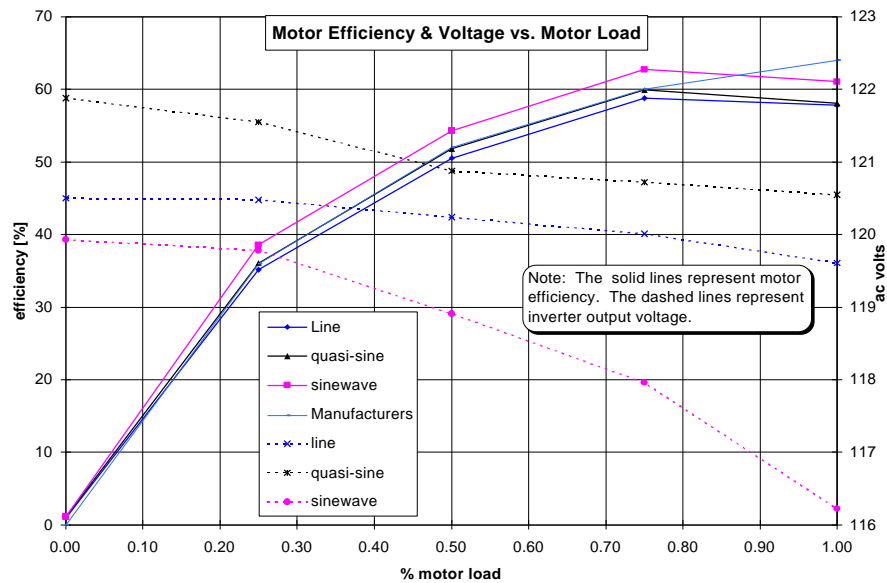


- Background** It is important that photovoltaic (PV) inverters be able to start motors and run them efficiently. When started from line voltage, the surge current associated with a motor start is up to six times the steady-state current. Starting the same motor from an inverter may result in a lower peak current; however, the motors can often still be started and operated. Additionally, harmonics cause heating in motors (see Freund, EC&M Set 87, page 70) and thus motor efficiency may be expected to be lower for inverters with high harmonic content. To evaluate motor-starting capability and motor efficiency SNL conducted a series of tests with line voltage, a sinewave inverter, and a quasi-sinewave inverter. The motors were loaded with a dynamometer so that performance at various loads could be evaluated.
- Objective** The purpose of the tests was to determine the ability to start and to evaluate the efficiency of induction-run, capacitor-start motors powered by a PV inverter.
- Units Tested** The inverters used to power the motors were the Heart Freedom 20, a 2-kVA, quasi-sinewave inverter and the Trace SW4024, a 4-kVA, sinewave inverter. Baldor induction-run, capacitor-start, motors of 1/4, 1/3, 1/2, 3/4, and 1 hp were used in the tests. These are split-phase motors with a capacitor in series with the start windings and are common in household appliances. A centrifugal switch disconnects the start windings when the motor achieves approximately 70% of its running speed. The addition of the capacitor causes the current flowing through the starting windings to lead the current through the run windings by 90°, providing higher starting torque at lower current.
- Test Results** **1. Detailed comparison of three sources for a 1/2 hp motor.** The parameters of interest include motor efficiency, voltage sag and regulation, and surge current. The motor efficiency is the mechanical power out of the motor divided by the electrical power into the motor. The measured efficiencies for the three voltage sources and the manufacturer's data for the Baldor 1304 motor are shown in the figure below. The manufacturer's specified motor efficiency curve overlies that measured by using the quasi-sinewave inverter. The motor efficiency is slightly higher when powered by the sinewave inverter and slightly lower when powered by line voltage. Similar data was acquired on other motors.



2. Evaluation of a motor start with fully loaded inverter. For these tests the inverters were fully loaded by placing a resistance in parallel with a fully loaded motor. **The parallel combination drew the full inverter rated output load when the motor was at steady-state and is referred to as a fully loaded inverter.** A motor start is characterized by a few cycles of high amplitude current accompanied by a sag in the voltage. The following table lists the start characteristics of the Baldor L1304 motor when powered by the line or by a “fully loaded” inverter. Voltage regulation refers to steady-state operation, while sag is a transient parameter. The starting surge was quantified by the peak current and the number of cycles required to reach steady-state. The peak current drawn was 58 amps from the line and 38 amps from the quasi-sinewave inverter. Once steady state was reached, the operating power from all three sources is similar in amplitude.

Fully loaded inverter characteristics when starting a Baldor L1304 1/2 hp motor

	SNL line	quasi-sinewave	sinewave
voltage sag	9%	30%	33%
voltage regulation	1%	6%	4%
surge current (peak amps)	58	38	42
cycles to steady state	8	21	15

3. Comparison of three voltage sources with seven different motor loads. Finally, the voltage sources, with no parallel resistive loads, were used to start fully loaded motors. The results are summarized in the table below. The salient result was that the efficiencies of the motors were nearly the same, regardless of the voltage source. In fact, the motor efficiency using the sinewave inverter as a source was a little higher than the motor efficiency using the line as a source. The data indicated that the higher efficiency was due to the lower ac operating voltage of the sinewave inverter.

Fully loaded motor efficiency for three voltage sources

Motor	HP	Line		Quasi-sine inverter		Sinewave inverter	
		Efficiency	Voltage	Efficiency	Voltage	Efficiency	Voltage
L1203	0.25	55	120.0	57	120.9	58	117.8
L1206	0.33	57	120.1	57	121.5	60	117.4
L1209	0.5	60	120.0	59	120.1	62	116.6
L1303	0.5	65	119.7	64	119.9	64	117.3
L1304	0.5	58	119.6	58	120.5	61	116.2
L1305	0.5	57	120.0	57	120.2	58	117.6
L1307	0.75	64	119.4	63	118.6	65	115.6

Discussion The efficiencies of the motors evaluated were similar for similar loading. There was no significant loss in efficiency when using a quasi-sinewave inverter. The motor efficiencies for inverters were essentially the same as those for line excitation. The inverters (especially smaller inverters) supplied less peak current than the line voltage; however, they were able to start the motors. The number of cycles of surge current that was required is inversely proportional to the amplitude of the start current.

Significance Both quasi-sinewave and sinewave inverters were able to start and run the motors that were evaluated, even when the surge power required to start the motors exceeded the inverters rated value. Inverters can start motors with significantly less current than the motor will draw when connected to a commercial line. The motor will start with reduced current and the inverter will not be damaged.

**For More
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